MEMOIR 114 MARCH, 1928

CORNELL UNIVERSITY
AGRICULTURAL EXPERIMENT STATION

# BUILDING UP RESISTANCE TO DISEASES IN BEANS

DONALD REDDICK

---

ITHACA, NEW YORK
PUBLISHED BY THE UNIVERSITY
Received for publication April 28, 1927

# BUILDING UP RESISTANCE TO DISEASES IN BEANS

DONALD REDDICK

The common field bean (*Phaseolus vulgaris* L.) as grown in New York is subject to a number of diseases and insect pests (Burkholder and Hawley, 1923). Two of the common and destructive diseases occurring in the State are anthracnose (caused by *Colletotrichum lindemuthianum* (Sacc. & Magn.) Bri. & Cav.) and mosaic (cause not known). With the work of Barrus (1911) it became known that there are two separate and distinct races of the anthracnose fungus which morphologically are identical but which biologically are very different. These races were named *alpha* and *beta*. From the practical standpoint, therefore, two separate anthracnose diseases were shown to exist. After extended experimentation, Barrus reported (1918) on the behavior of a large number of varieties of beans when inoculated with these two races of Colletotrichum and the plants placed in optimum conditions for infection and the development of disease. Only two varieties of field beans were found to be very highly resistant or practically immune for both races of the fungus. These were Wells' Red Kidney and White Imperial.

Subsequently, Burkholder (1923) reported a third race of *Colletotrichum lindemuthianum* which he named *gamma* and which has the ability to infect, among other bean varieties, both Wells' Red Kidney and White Imperial. The existence of the *gamma* race was not known at the inception of the work to be reported below.

Likewise the work of Reddick and Stewart (1918) has shown for the mosaic disease that, of a large number of varieties tested, only one showed complete immunity to the disease. This was a selection which was submitted for test by the late Professor Spragg, of the Michigan Agricultural Experiment Station, and which he finally described (1921) under the name *Robust*. This variety, like its progenitor Navy Pea, is susceptible to *Colletotrichum lindemuthianum*, race *alpha*, is practically immune to *beta*, and, fortunately for the outcome of this work, was found by Burkholder (1923) to be immune to race *gamma*.

The work of Burkholder (1918) and of McRostie (1921) on bean breeding for disease resistance, which was in progress in 1917, was well known to the writer. The progress of their work led strongly to the belief that suitable hybridizations would lead to the development of beans which would combine the resistance to anthracnose of each parent and the immunity to mosaic of one.

On the day (October 24, 1918) that Dr. Barrus terminated his inoculation experiments with the variety White Imperial, from which he con-

cluded that this variety is highly resistant for the *alpha* and *beta* races of *Colletotrichum lindemuthianum*, he communicated this conclusion orally to the writer. Several plants both of White Imperial and of Robust stood on the greenhouse bench in full bloom. Reciprocal crosses were made on that and subsequent days as flowers reached a suitable stage for artificial cross-pollination.

## MATERIALS AND OBJECTIVE

There are many dry-shell beans of various sizes, colors, and shapes on the market. In addition there are perhaps more which are grown in a limited way for home consumption. There is no reason to believe that many of these are really worth perpetuating, at least so far as intrinsic worth is concerned. It seemed desirable, therefore, to concentrate all effort on the production of a white bean which would conform to certain of the types now in large commercial production, such as White Marrow, Navy Pea, and Burlingame (Medium).

White Imperial does not conform to any of these types. The variety requires a long growing period to mature fully. This restricts the area in New York in which the variety can be produced at all, and, perhaps equally important, it interferes with a well-established and very satisfactory system of rotation which is followed in most of the New York regions of greatest bean production and which involves the fitting of bean land for seeding to winter wheat. In addition, the shape of the dry seed does not conform to any of the well-known types. It is oblong. It is not plump enough for White Marrow, nor for Medium. It is much too long for Navy Pea, and it is too straight and too short for White Kidney, a type which is fairly well known in the trade. White Imperial also is of determinate growth. This is regarded by some growers as an undesirable character. They claim, for example, that in case of unfavorable weather at flowering time there is more chance for the plants of indeterminate growth to set a crop. The exact importance of this factor does not seem to have been an object of study, and it may be questioned whether it more than offsets the advantage of having the pods held clear of the ground at harvest time when the crop may be destroyed by rot and mold following wet weather. Aside from its very high resistance to anthracnose, the variety has, to commend it as a parent, its very large and vigorous growth.

Robust, on the other hand, has much in its favor. It is a high-yielding typical Navy Pea type. It is immune to mosaic and practically immune to race *beta* (and subsequently was found practically immune to race *gamma* and also possessing more resistance to bacterial blight than most of the varieties in cultivation). The only characters that could be called objectionable are that the variety is very susceptible to race *alpha* and

that it requires a slightly longer growing season than Navy Pea. The particular stock used for hybridizing was obtained from Professor Spragg under the numbers 40511, 40515, 40516, 40520. As grown at Ithaca these various lots were progressively prolific and progressively late in the order indicated. Of these lots, No. 40516 was used oftenest and is the one most involved in the subsequent account.

In a very few cases Wells' Red Kidney was used instead of White Imperial. The variety had nothing to commend it except its very high resistance to both *alpha* and *beta*. Both color and shape of seed are characters that affect the progeny adversely in that they yield sorts which must be discarded because they are off type. Likewise, the extreme susceptibility of this variety to the bacterial blights makes it an objectionable parent. The variety has determinate habit of growth, like White Imperial, and is, in consequence, subject to the so-called objections mentioned for that variety.

## METHODS OF WORK

### *Pollination*

Cross-pollination is easily effected. The work was done in the greenhouse, where no unusual precautions had to be observed. If the flower is emasculated when it is too young, it usually falls off; and if the pollination is made after the flower is open, selfing usually has occurred and no hybrid results. In the varieties employed the optimum time for pollination seemed to be just as the standards of the corolla begin to show signs of separating.

The seeds of both parents would germinate immediately on maturity, but the seeds of the first-generation hybrids usually would not. Some such seeds that had lain in soil for several weeks were finally dug up and the seedcoat cut through with a knife and partially removed. The seeds were replanted at once and thereupon germinated promptly.

### *Inoculation*

Resistance to a single strain of anthracnose has been shown to be due to a single factor difference and to be a dominant character. The first generations were not tested, therefore, for anthracnose resistance. Neither were they tested for mosaic, since, at that time, McRostie's work (1921) did not permit him to say for a certainty just how mosaic resistance is inherited.

The second-generation plants were inoculated several times with a heavy spore suspension of races *alpha* and *beta* of *Colletotrichum lindemuthianum*. These plants were twice inoculated for mosaic, first on one juvenile leaf and after one or two days on the other.

*Segregation*

In the case of anthracnose a fairly sharp segregation was soon evident. All affected plants were discarded without record. Unfortunately, certain plants which did not show more infection than was produced on White Imperial by race *alpha* were saved for further test. Eventually all such progenies were discarded.

The segregation for mosaic was not so easily effected. The principal difficulty in this connection lies in the fact that there is no positive method of securing 100 per cent infection even on a susceptible variety such as Navy Pea. Furthermore, the symptoms of mosaic do not come out sharply in the greenhouse during the short cloudy days of winter, such as usually prevail at Ithaca, or in the field in summer if the weather is very warm and dry. On this account one lot of plants reached the sixth generation before it was finally discarded as susceptible to mosaic. Then, too, some of the plants, following White Imperial, did not show clear-cut cases of mosaic, and it became necessary to make inoculations from such plants on a susceptible variety.

*Field tests*

As soon as the quantity of seed warranted it—and usually this was in the fifth generation—the plants were grown in the field where they were subjected to the usual vicissitudes. When the lots were small, susceptible varieties (Navy Pea and White Marrow) were grown in the same row and inoculated; but later the susceptible varieties were mixed and grown in alternate rows. The anthracnoses were introduced as soon as the plants were well out of the ground, and in this way a very severe field test was secured in practically every year. In the early stages it was possible to inoculate every plant for mosaic, but later only a relatively small number of plants could be inoculated. Unfortunately, mosaic has never been observed to spread naturally in the test plots. Many susceptible varieties have been grown in adjacent rows every year, and Navy Pea, which is extremely susceptible to mosaic, has been used each year for a check and inoculated both for mosaic and for anthracnose. Small lots of plants were grown in the greenhouse from winter to winter and tested for mosaic. The progeny of such plants was marked for special observation the following summer in order to locate any that did not show clear cases of mosaic in the greenhouse. This is a very desirable precaution to take, as it is an excellent check on winter tests, due to seed transmission of the disease.

*Isolation of types*

Sorting for growth types, seed types, earliness and lateness, and so forth, began in the third generation. The sorting was not done too vig-

orously. Some lots that gave little promise were carried in small quantity from year to year, and in a few instances yielded, on further selection, types which have considerable promise.

### RESULTS

In the summer of 1922, 58 selections remained in the test. All of these families were in the sixth to the tenth generation, the exact generation depending upon the number of times greenhouse cultures were produced. None of the plants was susceptible to either race of the anthracnose fungus under the most severe conditions that could be imposed in field or in greenhouse. They had been subjected to possible infection, from the stage of tender dispirited seedlings as grown in the weak light of midwinter, through a great variety of telluric conditions in the field, and had shown no infection whatever. They were immune. Also, so far as could be determined, they were immune for mosaic. There were lots of early-maturing and of late-maturing plants, plants of determinate and of indeterminate growth, seed types of typical Navy Pea and White Imperial with many intergrading types, one of which approximated White Marrow in size and was of the exact shape of this popular variety.

### RACE GAMMA

Some of the lots had reached the stage where they might be put in a test for production, when race *gamma* was cultured and identified by Burkholder (1923). This race was isolated from White Imperial, but when it was found that it did not infect Robust it appeared that some of the hybrids might prove resistant. This seemed the more likely in view of the results which Burkholder (1923 : 322) had obtained with a Robust-Wells' Red Kidney hybrid and which he subsequently published. On August 11, 1922, and on September 15, a sample of each lot of the hybrids was inoculated in a large moist chamber with race *gamma*, the culture being very kindly supplied by Dr. Burkholder. The following record for ten consecutively numbered lots of plants will show what was found throughout this and subsequent tests. In these fractions, the denominator represents the number of plants inoculated, and the numerator the number that became infected—1/9, 3/10, 8/8, 4/5, 2/5, 2/5, 1/4, 0/2, 2/5, 5/5, and so on. In this test Wells' Red Kidney and White Imperial were severely affected, whereas Robust and White Sickel were entirely free.

All plants that showed resistance to the new race were grown to maturity and the progeny was grown in the field in the summer of 1923. All three races of the fungus were introduced early and gave good infec-

tion on the susceptible varieties. The season was very satisfactory for elimination of mosaic, but anthracnose never became abundant. Greenhouse tests were continued immediately after the field harvest. No crop was grown in 1924. In 1925 the following field notation was made: "Very heavy infection eventually resulted and by the end of the season the test could be called the most severe to which the hybrids ever have been subjected." A similar notation was made for the season of 1926, with the addition that the cold and wet summer gave valuable information on the behavior of the late-maturing varieties and on the relation of determinate and indeterminate growth to staining, mold, rot, and premature growth of seed.

## CONCLUSIONS

The evidence presented above has been summarized from a mass of notes and records covering seven years. There seems to be no occasion to publish the notes in detail, but they will be preserved and may be consulted by any one who cares to see them. When it is borne in mind that for all practical purposes four separate and distinct diseases are involved in the work, it appears that material progress in building up resistance to diseases in common field beans has been made.

The relative ease with which the work has been done indicates that this method of attacking the whole problem of disease control in plants gives promise of a condition of permanent control which deserves the widest attention. That other investigators are coming to a similar conclusion is obvious from a perusal of disease-control literature of the past decade, and more particularly of the past five years. Considering the enormously successful results obtained in the classical examples of permanent control of disease—the European control of Phylloxera of the grape by the use of resistant stocks, the control of wilt disease of cotton, cowpea, and other plants by hybridization with a resistant parent, and so forth—it is a matter of surprise that even more attention has not been given to this method.

It is not to be concluded at all that the hybrids developed in this work will go at once into commercial production and eventually replace the present sorts. Some of the problems remaining to be considered are discussed in succeeding pages. In the meantime, however, any worker who desires samples of these hybrids may have them in small quantity for any further work along this line that he cares to undertake.

## DISCUSSION

So far as the introduction into commerce of any of these particular hybrids is concerned, there are certain very definite things that remain to be found out.

*Practical problems*

*Yield.* Chief of the practical problems involved is, of course, the production record. A new variety that does not yield somewhat more than the average per acre of the standard sorts would not be accepted by growers. The present average reflects the losses in years of disease. A new variety which cannot equal the yield of the standard sorts in years when there is no disease clearly has very little to commend it. About the only advantage in the use of the new variety would lie in a tendency to eliminate fluctuation in yield (with attendant fluctuation in price), but as compared with the general character of the growing season and its effect on yield the elimination of the factor of disease might not produce a significant effect. At least this would be likely to be true in the case of such diseases as anthracnose, where severe losses occur only at intervals. In the case of a disease such as mosaic, however, the losses may be so great that the crop must be abandoned altogether. This was true in 1916 to 1918, in those parts of New York where Navy Pea beans were grown. Mosaic became so severe that this variety could not be grown. The substitution of the mosaic-immune Robust for Navy Pea occurred in these areas just as rapidly as seed of the new sort could be produced. In this case, however, the substitute is better than the original in every respect.

Minor objections to type of growth and the like might be easily overcome if the financial return can be shown to be adequate. But a variety that does not fit in readily with an established cropping system would have little chance to succeed.

*Trade demand.* The new variety must conform to the so-called "demand of the trade." While it may be true that a Bostonian housewife requires the variety Yellow Eye for baking, it is equally true that the demand of the average housewife rarely goes beyond a white bean or a colored one. This statement is easily confirmed at any public market. The demand for particular kinds of beans comes clearly from those consumers who use very large quantities of beans for canning purposes and the like, and from the dealers who must handle still larger quantities. The kinds of beans that are now on the market seem to satisfy present demands, and in general only the hybrid which conforms to some one of these types is worth offering to the public.

The quantity of seed now on hand is sufficient to begin comparative yield tests. After one more year the stock should be large enough for field tests in the various bean sections. The field tests are necessary because varieties that require more than one hundred days from planting date to harvest cannot receive a fair test at Ithaca, although they might mature very well in one hundred days if grown in a region where the

total amount of radiant energy was greater for the period or even if it were distributed differently; and there are places in the State where the growing season for beans is one hundred and twenty days or more. Likewise those sorts that mature at Ithaca in eighty-five to ninety days might mature differently elsewhere. Furthermore, varieties that do not yield well on the heavy clay soil at Ithaca might produce very well on a different type of soil. Burkholder found this to be true in the case of Perry Marrow (oral communication).

*Biological problems*

Several of the problems just referred to as practical are essentially biological in nature but have to do with the inherent qualities of the plants themselves. There are in addition some external biological conditions that may bear on the problem.

*Bacterial blight.* If the hybrids should prove particularly susceptible to bacterial blight, their usefulness in New York culture would be decidedly limited. It is to be noted that Wells' Red Kidney is especially susceptible to this disease (or group of diseases) and that the advantage of anthracnose resistance is practically offset by the disadvantages of blight susceptibility.

Bacterial blight has been found in certain of the hybrids and a record made of its occurrence and severity. No systematic inoculation of the plots was undertaken, but the use of Wells' Red Kidney in alternate rows has given abundant opportunity for natural spread of the disease and it is likely that the absence or the infrequent occurrence of the disease in some of the hybrids suggests that they possess a considerable resistance to the disease—certainly as much resistance as Robust, which has been classed by Burkholder (1924) as among the more resistant of a large number of varieties which he has tested.

*Root-rot.* The root-rot disease, caused by *Fusarium martii* f. sp. *phaseoli*, is a factor to be considered in producing field beans in practically all parts of New York. Burkholder (1919) has shown that, in infested soil, annual losses from this disease range from 5 to 50 per cent of the crop. He has recorded also (1919:1030) the existence of a resistant variety of very undesirable type. Although second-generation hybrids with this type were in existence as early as 1919, it is significant that no root-rot-resistant plant has yet been offered to New York farmers. Burkholder remarks that a very complex segregation has been found to exist in the hybrids made, and this doubtless has complicated the problem especially as the resistant parent is undesirable in a number of characters. McRostie (1921) suggests tentatively a two-factor hypothesis to account for the inheritance of susceptibility to root-rot. Thus far nothing further on this question seems to have been offered.

The hybrids in the present work have been tested to a limited extent in the greenhouse for root-rot toleration. The data show that some of the families are very susceptible and that others are decidedly resistant. It was inadvisable to inoculate plants in the field when the number was rather small, but now that the original purpose of the work has been accomplished the tests for root-rot tolerance can be executed although to do so means the introduction of the organism into land where it does not now exist.

*Rust.* In some sections of the United States the bean rust, caused by *Uromyces appendiculatus*, has been a serious factor in production. This disease seems never to have been important in New York. Random cases have been detected, especially on snap varieties and on Navy Pea. In two different years a trace of rust has been found on a few plants in the hybrid plots. In each case the infection probably came from Kentucky Wonder Wax or Golden Cluster Wax, both of which varieties have usually grown in close proximity to the hybrids and on both of which rust has been observed late in the season.

*Anthracnose.* That other races of *Colletotrichum lindemuthianum* exist has been demonstrated already by Leach (1923) and by Muller (1926). Unfortunately the varieties of beans employed by Leach in his work are not varieties that have been used by other workers nor are they known in the trade, so that there is no way of knowing at present whether or not the eight races that he describes are distinct from the three already known. Muller, on the other hand, obtained American material for comparison with four races which he isolated in Holland, and shows that the Dutch forms are different from those in New York. He also inoculated the seven differential varieties which were supplied him by Leach, and finds that two of his races behave alike on all seven varieties and therefore are like Leach's race VIII. But, from his tests with other varieties, he knows that they are biologically different. It is to be noted that Barrus found and recorded some variations in his work, but concludes (1918 : 597) that "we have been concerned here with only two strains of the pathogene." Leach (page 10 of reference cited) "does not consider this justifiable, because, if we consider difference in parasitism a sufficient basis for distinguishing biologic forms, a difference cannot justly be disregarded even if manifested on one host only. Furthermore, these forms may act differently on many other bean varieties which were not inoculated." Muller, in turn, quotes Leach's objection and uses it as a criticism of Leach's work. Just what the true situation is remains to be determined. Barrus points out that there may be variation within the host variety itself, and that a certain amount of cross-pollination which occurs naturally also may account for some of the variations which occurred in his tests. Of Leach's work it is to be noted

that his conclusions in some instances are based on very meager data. It appears from his table 2 that his biologic form VII is established on a single inoculation of from three to six plants of the test variety. It appears also, from his discussion on pages 5 and 6, that the organisms used varied as much as two years in the time at which they were first brought into artificial culture. While there is no definite information that these races lose virulence in culture, there are inferential data on this point in the experience of those at this institution who have worked with the organisms. Burkholder (1925) has shown a positive case of attenuation in *Fusarium martii* f. sp. *phaseoli*, and the phenomenon is well known in the case of many bacterial parasites of animals and man.

The race which has been isolated at Bonn and studied comparatively by Böning (1926) corresponds most nearly with the *beta* race. But if the Leach formula is applied, it would appear that the Bonn race is distinct. Böning says (page 8 of reference cited): "Von den 14 in Amerika widerstandsfähigen Sorten müssen 2 als sehr anfällig gegenüber dem hiesigen Pilzstamm gelten, 4 weitere werden, wenn auch nur in geringem Grade, befallen, während die übrigen 8 Sorten auch wohl unter hiesigen Verhältnissen widerstandsfähig sind."

Although it seems somewhat unlikely (owing to the number of cases), there is, of course, the possibility that the seed which Böning obtained for his tests is not of the same varieties as were used by Barrus or Burkholder. Such mistakes in naming varieties are not uncommon, and, as is well known, different varieties are sometimes offered for sale under the same name. Furthermore, the condition described by Salaman (1926), for potato, may well apply in the case of beans. He records that a newly introduced variety occurs in England which is partly immune and partly susceptible to the wart disease. Such a condition actually existed in the hybrids reported here before they were sorted for susceptibility to the *gamma* race.

Obviously, one of the next things to do is to make tests with all of the known races of *Colletotrichum lindemuthianum*. Even then, however, one could never be sure that a new race might not appear at any moment from some variety of beans which might be brought into a given locality. Such an event might be expected in the case of garden varieties, where novelties are being introduced almost yearly by a large number of seedsmen. In the case of field beans, however, the tendency seems to be in the other direction. Fewer varieties of staples are desired, in order that standardization may be effected. It is very unlikely that a new variety

---

"It has happened within the writer's knowledge, that a newly introduced variety [of potato] consisted in reality of the product of two seedlings so much alike that no differentiating external features which would serve to distinguish them could be found, and yet one seedling was immune and the other susceptible to Wart Disease."—Salaman (1926:16).

of dry-shell bean will be introduced in the fields of New York until it is known to conform to some one of the standard varieties now in cultivation, and even then it is not too much to expect that such a variety would not be accepted by growers unless they were assured that it was as good as or better than the standard, not only in yield and conformity to type, but also in resistance to diseases.

Further, it is always possible that these hybrids might prove to be resistant to the new race. Certain varieties of snap beans always have been grown in close proximity to the hybrids, and some of these always have been sorts that were bought of seedsmen. One year, indeed, the organism was taken from these varieties of unknown origin and was mixed with the three races to make a general inoculation. No attempt was made to determine which races may have occurred on these varieties, but it was evident from the behavior of the plants used for check that nothing which could be called certainly new had been introduced.

### OTHER RESISTANT VARIETIES

Finally, it may be added that in case none of these hybrids proves to be a desirable commercial sort and it seems impossible to secure a desirable type by the use of these parents, there exist some other varieties which possess a high degree of resistance to the three races of *Colletotrichum lindemuthianum* and which are very tolerant to mosaic. A large number of varieties have been grown for several years in a parallel row with the hybrids, and usually have been inoculated in the field along with the hybrids.

*Nova Scotia Marrow.* One of these varieties is in commercial production at the present time under the name *Nova Scotia Marrow.* The plant is determinate in growth habit, whereas White Marrow, which is susceptible to races *beta* and *gamma*, is indeterminate. The dry seed of the two varieties is very nearly of the same size and shape, and is readily interchangeable. An objection to Nova Scotia Marrow is that the cotyledons are likely to split apart somewhat, as the seeds dry down in the pod. The operation of threshing separates some of these, and, as a result, the pick is relatively high.

Some other varieties which have reacted like the Nova Scotia Marrow, but which from color or shape of seed do not offer such obvious possibilities, are listed herewith. These varieties mostly are not known in the trade and cannot be certainly identified by the use of Jarvis' work (1908).

*Yellow-Eye Navy.* A variety was procured from the John Lewis Childs Company in 1917 as new under the name *Yellow-Eye Navy.* The seeds at present approximate Yellow Eye in size and marking, and seem to be larger than when originally procured.

*Soldier bean.* A variety known as *Soldier* was procured from an exhibit of the New Hampshire Horticultural Society, and was said (in 1916) to be grown locally. The dry seed has the shape and appearance of White Kidney—white, with markings about as extensive as in Yellow Eye but of vinaceous color. The plants are determinate and large.

*Sulphur bean.*—A variety known as *Sulphur* was procured at the same time and place as the Soldier bean. In seed characters it corresponds most nearly with Eureka, but is smaller and more nearly round. It differs from Eureka also in its resistance to race *gamma.*

*Leopard.* Another local variety from New Hampshire, known as *Leopard,* is also very highly resistant to anthracnose. This is not the stringless snap bean described by Jarvis under this name, but a dry-shell variety. The dry seeds of this variety are about the size of White Imperial, but are colored on the ventral side a deep bluish purple, and have spots of this same color all over the dorsal side which otherwise is white.

*Boston Beauty.* Another local variety from New Hampshire is Boston Beauty. The seeds are somewhat shorter than those of Leopard, but they are marked like them except that the color is vinaceous red.

*Jacob's Cattle.* Another local variety from New Hampshire, Jacob's Cattle, is very much like Boston Beauty but the seeds are larger and longer and the seed is more nearly covered with vinaceous red color.

## BIBLIOGRAPHY

BARRUS, MORTIER F. Variation of varieties of beans in their susceptibility to anthracnose. Phytopathology **1**: 190–195. 1911.

———— Varietal susceptibility of beans to strains of *Colletotrichum lindemuthianum* (Sacc. & Magn.) B. & C. Phytopathology **8**: 589–614. 1918.

BÖNING, KARL. Ueber die Empfänglichkeit von *Phaseolus vulgaris* für *Colletotrichum Lindemuthianum* im Lichte der Rassenbildung des Krankheitserregers. Forsch. Geb. Pflanzenkr. u. Immunität im Pflanzenreich, 2 Heft: 1–18. 1926.

BURKHOLDER, WALTER H. The production of an anthracnose-resistant White Marrow bean. Phytopathology **8**: 353–359. 1918.

———— The dry root-rot of the bean. Cornell Univ. Agr. Exp. Sta. Memoir 26: 997–1033. 1919.

———— The bacterial blight of the bean: a systemic disease. Phytopathology **11**: 61–69. 1921.

———— The gamma strain of *Colletotrichum lindemuthianum* (Sacc. et Magn.) B. et C. Phytopathology **13**: 316–323. 1923.

———— Varietal susceptibility among beans to the bacterial blight. Phytopathology **14**: 1–7. 1924.

———— Variations in a member of the genus Fusarium grown in culture for a period of five years. Amer. journ. bot. **12**: 245–253. 1925.

BURKHOLDER, WALTER H., AND HAWLEY, I. M. Diseases, and insect and animal pests, of the field bean in New York. Cornell Univ. Extension bul. 58: 1–38. 1923.

JARVIS, C. D. American varieties of beans. Cornell Univ. Agr. Exp. Sta. Bul. 260: 147–255. 1908.

LEACH, J. G. The parasitism of *Colletotrichum lindemuthianum*. Univ. Minnesota Agr. Exp. Sta. Tech. bul. 14: 1–41. 1923.

MCROSTIE, G. P. Inheritance of disease resistance in the common bean. Amer. Soc. Agron. Journ. **13**: 15–32. 1921.

MULLER, H. R. A. Onderzoekingen over *Colletotrichum lindemuthianum* (Sacc. et Magn.) Bri. et Cav. en *Gloeosporium fructigenum* Berk. forma *Hollandica* nova forma. Landbouwhoogesch. te Wageningen (Nederl.). Meded. **30**: 1–93. 1926.

REDDICK, DONALD, AND STEWART, VERN B. Varieties of beans susceptible to mosaic. Phytopathology **8**: 530–534. 1918.

SALAMAN, REDCLIFFE N. Potato varieties, p. 1–378. 1926.

SPRAGG [SPRAGUE], F. A., AND DOWN, E. E. The Robust bean. Michigan Agr. Coll. Agr. Exp. Sta. Spec. bul. 108: 1–11. 1921.

Memoir 100, *A Study of Pogoniris Varieties*, the fourteenth preceding number in this series of publications, was mailed on May 25, 1927.